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ABSTRACT

Finding an unequivocable answer to the class size issue is vitally important to the future of American public education. Sorting out conflicting viewpoints and determining supportable conclusions are this report's primary purpose. Three factors--research motivation, the effects of confounding variables, and problems related to distinguishing between student achievement and other classroom process changes--are largely responsible for the divergent, sometimes conflicting views expressed in the literature. For all student populations, class size research shows an important link between lowered student/teacher ratios and higher achievement. This conclusion can be reached by using appropriate complex statistical methods and research designs promoted by the National Education Association. An extensive literature review yields seven related conclusions: (1) class size research has had a history of limited research design, inappropriate methodology, and biased literature reviews; (2) the most seriously misleading conclusions have often been repeated in subsequent analyses; (3) development of a theoretical framework for determining class size influences on learning has been slow; (4) various studies have shown that achievement effects are mediated by changes in teachers' handling of classroom responsibilities; (5) alternative cost-effective strategies for reducing effective group size are available; (6) redeployment of existing school staff offers the most promising strategy for reducing instructional group size; and (7) some class reduction benefits can be gained by creative redistribution of students and incorporation of small-class techniques into routine classroom practice. One statistical appendix is included. (269 references) (MLH)

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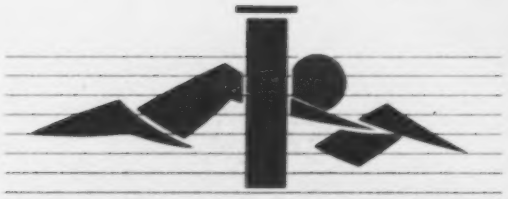

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How Changing Class Size Affects

Classrooms and Students

Douglas Mitchell
Cristi Carson
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How Changing Class Size Affects Classrooms and Students

> Of all the beliefs held by American educators, few are more durable than the proposition that smaller classes will yield higher student achievement. It is one of the great "givens" of education in this country. It may also be a very expensive excuse for instructional failure.
>
> Chester E. Finn, Jr.
> Assistant Secretary of Education
> (Tomlinson, March 1988, p. iii)

Conflicting Research Findings

Secretary Finn's remarks put the issue of class size into clear and challenging perspective. Are educator beliefs regarding the importance of small classes a matter of finely honed professional judgment? Or do they reflect the biased and self-serving views of public employees seeking reduced work loads or ready-made excuses for poor school performance? Finding an unequivocal answer to this question is vitally important to the future of American public education. If large class size is seriously eroding school productivity, it will require a dramatic reallocation of fiscal and human resources to overcome the problem. If, on the other hand, class size effects

are small compared to the impact of curriculum development, technology acquisition, or other promising school improvement mechanisms it must not be allowed to drain critical resources and undermine school reform.

Sifting through available research evidence and sorting out claims and counter claims regarding the relationship between class size and student learning is not easy. To the contrary, finding a clear answer to the class size question is at least as difficult as it is important. Scholarly literature on the topic is voluminous (the bibliography accompanying this review contains 276 citations covering various aspects of the class size question). Interpretation of that literature is complicated and fraught with controversy. Where one author insists that:

> . . . despite the volume of research on the topic, we really know very little about class size and class size effects. Almost eight decades of educational research and hundreds of studies have produced few verifiable generalizations to guide the formulation and implementation of educational policy (Berger, 1982, p. 2, emphasis added).

Another author reports:

> . . . the issue seems to have been settled: smaller classes promote higher achievement, better attitudes, different instructional practices, and higher teacher satisfaction and morale. Technical criticisms of methodology (see, e. g., Hedges, 1981), and less-substantiated criticisms of research by the Educational Research Service (1980), would not change the general interpretation of meta-analysis in this area (Glass, Cahen, Smith & Filby, 1982). (Bourke, 1986, p. 558, emphasis added).

In yet another review, we are told:

> Research indicates that the relationship between class size and instructional effectiveness depends on a multitude of related variables, such as the age level of students, subject matter taught, and instructional methods used (Ellis, 1985, p.1, emphasis added).

Sorting out these conflicting points of view and determining exactly which conclusions are supported, and which are not, is the primary purpose of this report.

Three factors -- researcher motivation, the effects of confounding variables, and problems related to distinguishing between student achievement and other classroom process changes -- are largely responsible for the divergent and sometimes conflicting views expressed in the literature.

Research Motivation. Major class size research studies have been prompted by very different motives and have, therefore, sought to answer very different questions. Concern with economic efficiency prompted the earliest studies -- researchers wanted to know how large classes could become before decline in achievement would more than offset savings in teacher salaries and facility costs. Later researchers were more concerned with individual student achievement and sought to determine how class size would optimize learning.

Confounding of Variables. Class size is but one of many variables that influence the behavior of students and teachers, and the effects of class size are easily confounded by these other school factors. In recent years,

research designs have become more sophisticated making it possible to statistically control and weigh the importance of these factors.

Many studies have overlooked the possibility that larger classes may be accompanied by other factors interfering with student learning. In too many cases, data are collected from students exposed to instruction in naturally occurring large and small classes. Such data are almost certainly affected by various administrative and political factors controlling class sizes in the schools. Advanced Placement English classes, for example, are more often smaller in size than the average general English course. No doubt, the generally higher achievement of students in the AP English class results from their selection of these classes, not from the small size alone. Similarly, rapidly growing schools generate larger classes containing students who are not typical of the general school population. Student ability, interest and family characteristics strongly influence achievement. Where class size is confounded with these other sources of achievement it is impossible to determine how much class size is contributing to learning outcomes.

While some individual studies have succeeded in controlling for these exogenous factors, it was the development of meta-analysis (Glass and Smith, 1978) as a method for statistically synthesizing the results of large numbers of studies that made it possible to look beyond the limitation of individual research studies and illuminate the broader picture.

Student/Teacher Attitude and Classroom Process Changes. Another important factor given careful attention in this review is the range of student outcomes affected by changing class size. Early studies of class size defined student learning entirely in terms of cognitive achievement. Mastery of subject matter, particularly reading and mathematics, was the primary focus of early research activities. Over time, however, increased attention was given to a variety of non-achievement outcome variables. Research analyzing the impact of class size on these non-achievement variables makes two important contributions to this report.

First, these findings help to identify the specific mechanisms by which lowered class size serves to increase the opportunity for students to attain greater mastery of academic subjects. By themselves, class size changes cannot be expected to affect student learning. Studies of non-achievement changes in teacher or student actions and attitudes show how achievement gains are produced, and suggest alternative strategies for getting the desired results.

Second, these attitude and classroom process studies focus attention on the fact that Americans seek more than mere optimization of academic achievement from their schools. While subject mastery is the number one priority, few would deny that parents expect schools to enhance students' self-concepts and encourage positive attitudes toward life and toward learning.

Taking a Policy Perspective

Despite troublesome problems encountered in trying to synthesize class size research, it is vitally important to view the key findings from a policy perspective. Adjusting class size is enormously expensive, and is of vital concern to education leaders at every level. For classroom teachers, class size is a critical factor in determining overall work load, and in controlling the level of classroom stress. For schools and districts, class size policy dramatically impacts facilities and program planning. For state and federal policy makers, class size is the single most important ingredient in determining the overall cost of public education. Without major organizational changes, substantial reductions in class size would require unprecedented increases in school funding -- virtually eclipsing all other initiatives for reform and improvement.

Putting the class size issue into a policy perspective requires that evidence drawn from the available research be marshalled to answer four key questions:

> **<u>Policy Question #1</u>. How much, and how reliably, does a reduction in class size lead to improvement in student achievement?**

This is, of course, the starting point for any policy deliberation. If student learning gains are slight, or are so unreliable that other factors completely overpower them, the only justification for investing in this expensive policy lies in a desire to make life more comfortable for teachers

or students. On the other hand, if the effects are substantial and cannot be easily produced by other means, failure to control class size would be a major stumbling block to overall school improvement.

Not surprisingly, the answer to this question is rather complicated. The link between class size and student achievement is analogous to the link between cigarette smoking and cancer, or that between burning fossil fuels and acid rain. Statistically speaking, the evidence is substantial and convincing -- but that does not mean that every small class produces greater learning. Just as surely as many smokers escape lung cancer, and that cancer strikes many who have never touched a cigarette, many small classes fail to teach materials that can be effectively taught to much larger student groups.

The evidence presented below will demonstrate, however, that policy makers ignore the class size issue at great risk. At a minimum, the class size research literature reminds us that investments in management, support staff, facilities, materials and other needed educational resources can and should be judged on the basis of their contributions to student learning. When schools allow class size to rise in order to support special programs or to release resources for other purposes, it is quite appropriate to ask whether the funds so used meet the test of improving student learning at least as much as would result if the resources were used to reduce the student/teacher ratio.

Policy Question #2. Exactly how do changes in the student/teacher ratio control learning outcomes?

While finding a substantial and reliable link between class size reduction and student achievement is sufficient to make the issue an important one, it does not settle the question of how schools should respond. To the contrary, until a clear picture of how class size changes affect teaching and learning processes in the classroom can be developed, it is impossible to determine exactly how to approach the issue. If, for example, the key to learning improvement is entirely a matter of changing the number of students assigned to each adult, the most economical strategy would be to add classroom aides or solicit parent volunteers to work in existing classrooms. If learning gains depend more on reduced noise levels or more focused interactions between teachers and students, however, the introduction of more adults into existing classrooms is likely to be counterproductive.

The evidence reviewed in this report reveals that the achievement gains produced in smaller classes are produced through identifiable changes in the behavior of both teachers and students. Where changed teaching and learning behaviors do not accompany reduced class size, achievement gains cannot be expected (Fox, 1967 and Wright, 1977). From a policy perspective, it is important to determine if these behavior changes are necessarily linked to the smaller class size, or could be generated through a less expensive or

perhaps more powerful means than by reducing the student/teacher ratio. As described in the third section of this report, careful analysis of the various classroom and learning process variables associated with small classes suggest that policy attention should shift from the concept of class size (with its emphasis on simply distributing students among a larger number of classrooms) to what might be called "instructional group size". That is, policy should address how instruction is organized, as well as how schools and classrooms are staffed. This leads to the third key policy question.

Policy Question #3. What are the organizational and fiscal implications of the documented link between class size and student achievement?

Any frontal attack on class size is bound to be expensive. Teacher salaries which are dramatically impacted by class size reductions, are the single most important ingredient in the cost of education. And the cost of facilities, another factor sharply impacted by any effort to reduce class size, is near the top of the list of educational cost ingredients. Hence, adopting a policy perspective on the issue of class size requires that we look carefully at optional ways of handling the multi-faceted organizational and fiscal aspects of the problem.

The evidence reviewed in this report indicates that the direct costs of class size reduction are well beyond the means of most states -- including California. Moreover, a review of existing school organization and staffing arrangements suggests that significant improvements in instructional group

size could be produced through less drastic measures. This observation leads to the fourth policy question.

<u>Policy Question #4</u>. What alternatives to direct increases in the number of teachers and classrooms in today's schools might produce the desired learning achievement outcomes?

Ultimately, policy analysis involves looking at the extent to which desired goals can be reached, or at least approached, using the most economical means. If we know what is needed to reap the benefits of reduced class size, and if we analyze the organizational and fiscal implications of making needed changes, we can often develop policy alternatives that can produce some or all of the desired benefits with fewer resources. Recent experiments with de-regulation of public services have been stimulated by a belief that innovation is likely to be too expensive if it is reduced to a matter of "adding-on" to existing institutional arrangements. The traditional assumption of the "egg-crate" school with its single schedule and uniform-sized, self-contained classrooms may need to be substantially altered in order to incorporate the best findings from class size research into day-to-day school operations.

The final section of this report summarizes a number of possible ways of adjusting school programs and operations to accommodate research findings. In particular, we explore possible ways of re-deploying existing teaching and support staff to provide the class size reductions and instructional practices most likely to enhance student achievement.

The Unfortunate History of Class Size Analysis

Viewed from a policy perspective, research on class size has a singularly unfortunate history. The problem is not so much that research in this area has produced divergent and contradictory findings. (That is more or less the norm for research work on complex social issues) The literature on class size has problems not ordinarily encountered, however. There is a decided tendency for reviewers to use hyperbole aimed at convincing readers, rather than informing them. More importantly, the literature is plagued by oft-repeated, very misleading assertions about the extent or nature of the relationship between class size and student achievement. Because of this unfortunate history, it is necessary to look at the historical development of the research on class size in order to answer the policy questions outlined above.

The Early History of Class Size Research. J. M. Rice is credited with conducting the first empirical research addressing how class size changes impact student achievement. Though it included no statistical data, his 1909 study concluded that there is no relationship between class size and student achievement. He found it "surprising", even "incredible" that, "no allowance, whatever, is to be made for the size of the class in judging the results of my test" (Rice, 1902, p. 28).

The Rice study was the first of several conducted between 1900 and the Great Depression aimed at applying efficiency models borrowed from

private industry to school programs. Established policy standards -- such as those of the *North Central Association of Colleges and Secondary Schools* (Michigan), limiting teacher workload to five instructional periods, and no more than 150 student contact hours each day -- were challenged by researchers who observed that "an enormous influx of pupils" entering the newly popularized high schools was causing the cost of public education to rise dramatically. As a result, their research attention was focused on determining whether,

> under the improved physical and disciplinary conditions found in the schools today as compared with the conditions obtained a generation ago, a longer school day, larger class sections, and a teaching load considerably greater than the norm of 150 student-hours of class instruction per day are not justifiable. (Davis, 1923, p. 412)

Class size research conducted prior to 1920 was primarily concerned with the effects of large classes on grade-to-grade promotion rates (Cornman, 1909; Boyer, 1914; Bachman, 1913; Elliot, 1914; and, Harlan, 1915). Standardized achievement tests came later.

Improved Research Designs. During the 1920's, scholars began employing newly developed intelligence and achievement tests and better experimental controls in their research designs. In class size research, these experimental controls included matching the students' abilities in the small and large classes and standardizing the instruction taught to both groups. Small classes during this period ranged from 20 to 25 students; large classes

contained as many as 70 students. By 1930, fully randomized research designs were being utilized.

Interested in how large classes could become before causing injury to the educational rights of individual children, Davis and Goldizen (1930) assessed the mental achievement of a group of seventh grade history students. The students were rank-ordered by their tested ability levels, and divided into two matched groups. A total of 140 students of medium ability were selected for the study. Seventy of the students were taught as a single unit; the other 70 were divided into two classes of 35 each. All three sections were pre-tested. After being taught history by Goldizen for one semester, all were post tested. The authors concluded that the pupils in the large class were at no disadvantage, and that it would be quite appropriate to utilize classes of this size for junior high school history instruction (Davis and Goldizen, 1930, p. 367).

This conclusion was almost immediately challenged in studies undertaken by F. L. Whitney (1930) and by Whitney in collaboration with G. S. Willey (1932). Whitney formed 24 matched groups, of 20 students each, at an elementary school in a Colorado mining community. For 16 weeks, 12 groups of 20 were taught as a single unit, while the other 12 were combined to form classes of 40. The achievement of the small and large classes were compared, and then the roles of the two were switched. (The 40 student groups were divided into two classes of size 20, and the original small classes were combined into groups of 40). At the end of another 16 weeks of

instruction, the achievement of students in the large and small classes was again measured and compared. Whitney found that 80% of his comparisons favored the smaller classes. Two years later, Whitney and Willey replicated the findings of this earlier study, and reported in the *School Executives Magazine* that:

> 1. Small groups experienced a lack of competition; and,
> 2. Large groups limited individualized instruction and made it difficult to keep adequate classroom discipline. (Whitney and Willey, 1932, p. 506)

Continued Interest in Larger Class Size. Class size research was not pursued during the Second World War, but interest became especially keen in the years immediately after the War. As the baby boomers began entering the schools, administrators once again focused attention on just how large classes could become without causing significant losses in student achievement, particularly at the high school level (see, for example, Good, 1970; Miglionica, 1958; Meillor, 1965; Anderson, et al., 1963; Haskell, 1964; and Jeffs and Cram, 1968). Sweeping conclusions drawn from limited and sometimes poorly designed studies were the norm. Madden, for example, using a randomly selected sample of nineteen general mathematics classes from seven high schools in Phoenix, Arizona, concluded that large classes are superior. The sizes of the experimental classes ranged from seventy to eighty-five students. His control classes consisted of a pupil/teacher ratio of

twenty-five to forty students, achieved either in single classrooms or by adding additional teachers to already existing classrooms. He concluded:

> Student achievement in general mathematics is significantly higher when students are taught in large groups (seventy to eighty-five students) as opposed to regular groups (twenty-five to forty students). (Madden, 1968, p. 622)

Although most studies of this era focused on increasing secondary school classes to accommodate expanding enrollments, the effects of large classes on elementary students were also challenged. H. J. Otto gathered data by questionnaire and interviews from fifty "small" and "large" second and fourth grade classes. At the conclusion of his analysis, Otto remarked:

> the total *educational program for children was not discernably different* in small classes from that found in large classes. (Otto, 1954, p. 145)

Smaller Classes Supported. Not all researchers during this period were influenced by the trend to increase class size, however. In a study, often cited for its careful design (see Glass and Smith, 1982; Robinson and Wittebols, 1986; Slavin, 1989), Irving H. Balow devised a method to provide elementary students with small classes for reading instruction. In his Riverside, California, experiment, one-half of each experimental class came to school an hour earlier each day to receive instruction in reading and language. The other half of each class received reading instruction the last hour of the afternoon, after the first group had gone home. Effective class size for reading instruction was thus reduced from thirty students in the

average class to fifteen in the experimental program. A stratified random sample of seven elementary schools began the program in 1962-63, with all children in grades one through three participating. The program continued for three years to determine whether the effects of small classes are cumulative. Results from yearly measures of reading achievement and mental maturity were analyzed and the following results were obtained:

> 1. When reading readiness and/or IQ are controlled in the analysis of fourth grade reading achievement, children in the experimental program for two or more years score significantly higher than other children.
>
> 2. When reading readiness is controlled and second grade achievement test scores are analyzed, children in the experimental program score significantly higher than children in the control group.
>
> 3. When second grade achievement is controlled and third grade scores are analyzed, children who began the program in the first grade gain significantly more than other children. This finding suggests that the influence of the program is cumulative, and adds statistical weight to the belief that the first grade is the critical year in reading instruction. (Balow, 1969, p. 186)

By the late 1960's, educational interest focused largely on the individual student. Whereas earlier, researchers had been intent on seeing how large classes could be made, the objective shifted toward assessing the benefits of small group instruction (e.g., Ellson, et al., 1965; Bausell, et al., 1972; Smith, 1974; and, Ronshausen, 1975). At the extreme, this research thread documented the advantages of individual and small group tutorials. Shaver and Nunn (1971), for example, received funding from the Elementary-Secondary Education Act to measure the effects of tutoring on students

identified as "underachievers" in reading and writing. Forty-six students whose deficiencies were not severe enough to qualify for remedial help, but who had not developed their full reading and writing potentials, were the subjects in this study. Experimental tutoring groups were formed at the ratios of 1 to 1 and 3 to 1. The control students were placed in regular sized classes (the identity of the control students was known only to the project director). Students were pre-tested, and post-tested after one year of treatment and again after two years. The post-test scores were adjusted to eliminate the effect of correlation with the pre-test scores. They found the effects of tutoring in these special need situations to be encouraging, especially significant were the higher English grades achieved by tutored students two years after the treatment had been discontinued.

Studies of Disadvantaged Students. A number of other class size studies were stimulated by passage of the Elementary and Secondary Education Act (Public Law No. 89-1, now Chapter 1) in 1965, (Cooper, 1989). Unfortunately, a good share of these studies have consisted of "pulling" the records of large numbers of students and applying regression analysis to compare the achievement (generally based on standardized tests) of "low-income" students in "smaller" classes against either their cohorts in "larger" classes, or against "high-income" students not receiving the benefits of the federal program funding (see, e.g., Castiglione and Wilsberg, 1968; Murnane, 1975; Counelis, 1970; Furno and Collins, 1967; Manos, 1975; Summers and Wolfe, 1975; Bowles, 1969; and Mazareas, 1981). These studies have

produced mixed results, leaving the issue of whether disadvantaged students derive any special benefit from class size reductions open to question. Doss and Holley (1982) are cited by several reviewers (i.g., Robinson and Wittebols, 1986 and Slavin, 1989) as providing insight in this area. These authors compared the achievement of students in small classes (15:1) with students of similar characteristics who were receiving Chapter 1 services in pull-out programs. Results from this study showed that the middle level students in the smaller classes outscored their counterparts (on the Iowa Test of Basic Skills) in the pull-out programs, but that differences between the scores of the low and high achieving students were not statistically significant. In another study, a More Effective Schools Program (MES) implemented at two elementary schools in Cleveland, Ohio, researchers combined lowering class size with team-teaching. The evaluators of this program reported that

> from the outset, the operation was confused and lacking in definition, with an abundance of equipment, materials, small classes and supportive personnel that few teachers knew how to use (Taylor and Fleming, 1971, p. 17).

After three years of operation, the reading and math achievement of students in the program who had been taught in groups of fewer than 26 were compared to students from other schools. The sizes of the comparison classes were not reported. The MES students' scores were consistently higher than the those of the non-MES students', but the performance of all the students involved still remained below grade level. The authors were

reluctant to make any definitive statements regarding the results of their study.

In 1968, Castiglione and Wilsberg evaluated the effects of class size changes in grades 1 and 2 as a result of an Early Childhood program in New York City. Class sizes in "poverty" schools were reduced to 15 to 1. A sample of project schools was randomly drawn and matched with classes of size 25 to 1 in the non-participating schools. On the whole, the project schools out performed the comparison schools. More recently, in a study of an updated Early Grade Improvement Program in New York City, very similar to the 1968 program, Jarvis and Schulman (1988) found that the second graders in the program were performing at grade level in reading and slightly above grade level in mathematics; whereas, before implementation of the program, students had been performing below grade level in both subjects.

Taken as a whole, research with disadvantaged students confirms the overall value of small classes, but still leaves the issue of whether disadvantaged students derive any special benefit from smaller classes open to question.

Summary. For all student populations, class size research, while difficult to synthesize offers convincing evidence of an important link between lowered student/teacher ratios and higher achievement. Reaching

this conclusion is not easy. As noted in a report by the National Education Association:

> a) the effects of class size reductions can only be found by using complex statistical methods;
>
> b) the better the research design, the stronger the effect of class size reductions found;
>
> c) older studies showed few or no effects while newer studies generally link achievement gains to lowered class size;
>
> d) documented class size effects deemed significant by one researcher may be viewed as insignificant by another; and,
>
> e) few studies examine changes in classroom activities or teacher behavior, making it difficult to see how apparent achievement gains are actually produced. (National Education Association, 1986, p. 1)

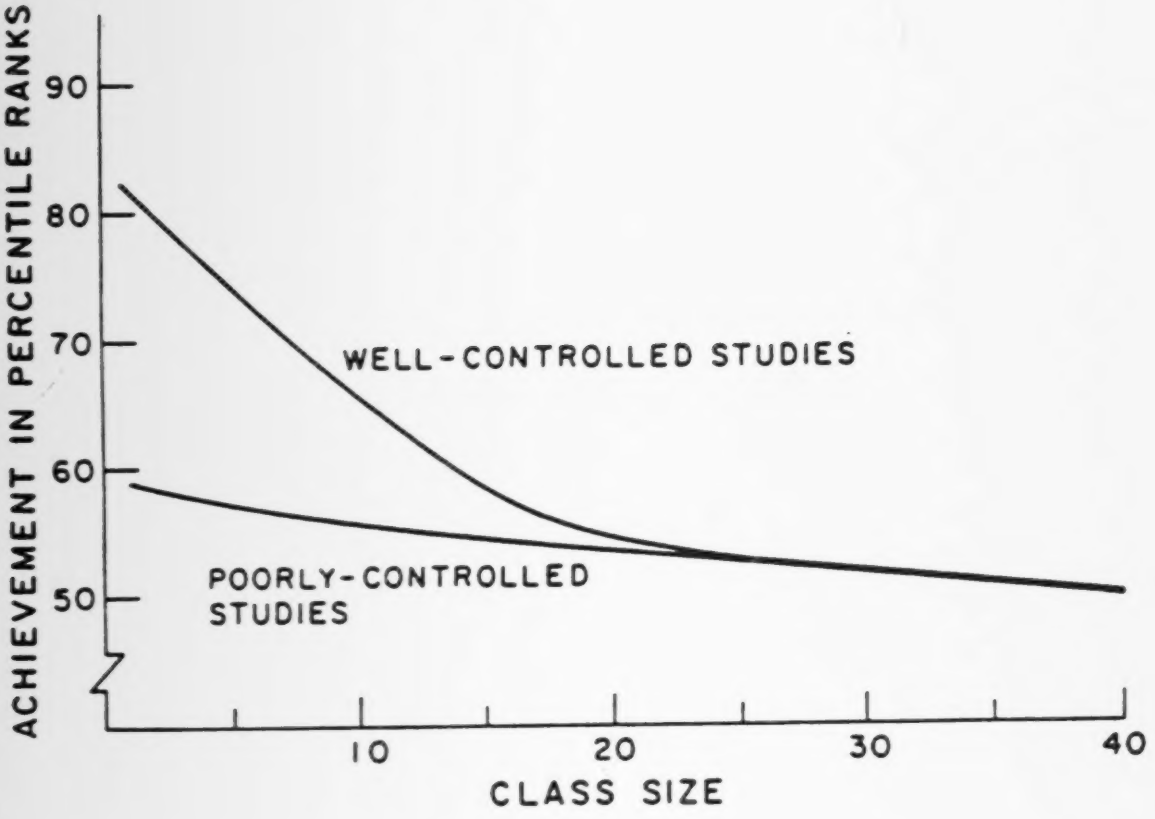
Meta-analysis: Sorting out the Literature. Systematic summary of findings from the growing corpus of class size research took a giant leap forward in 1978 with the development of a new statistical technique called meta-analysis. Seeking a comprehensive summary of available work, the Far West Laboratory for Educational Research and Development urged Glass and Smith (1978) to comprehensively review the extant literature. They identified approximately 150 studies containing statistical measures of achievement and non-achievement differences between pairs of small and large classes. Student academic effects were reported in 77 of these studies, spanning 70 years of work from more than a dozen different countries. These 77 studies contain a total of 725 different comparisons of pupil achievement in classes of at least two different sizes.

Using these 725 achievement effect measures, Glass and Smith set out to determine whether measured achievement differences are statistically reliable and, if so, how the relationship is best characterized. They began by developing a simple statistic, the "Effect-Size," to establish a standard measure of the relationship between class size and achievement. The objective was to create a measure that would allow all study results to be pooled, giving appropriate attention to research reports with zero or negative effects, as well as to those showing positive effects. The effect-size is defined as the difference between the mean achievement scores of the smaller and larger classes, divided by the standard deviation of the achievement scores in the larger class. Hence the effect-size is +1.0 if the difference between the average achievement of the smaller class exceeds the average achievement of the larger class by one unit of standard deviation. It is -1.0 if the large class outperforms the smaller one by one full standard deviation. This technique makes the effect-size statistic independent of the particular tests used to assess achievement, and largely independent of measurement reliability problems.

Analysis of the 725 effect-size estimates consisted of fitting them to a quadratic curve, using a least-squares regression technique. This approach produced a statistically powerful, but conceptually awkward, curve indicating that achievement drops off sharply when additional students are added to very small classes, but that the marginal effect of each additional student decreases as classes get larger. As shown in Figure 1, the regression

solution produced in this 1978 study demonstrated very clearly that one-on-one tutorial teaching strategies are far more effective than the typical school class of 20 to 40 pupils. The analysis indicated ordinary students who could be expected to score at the 50th percentile in classes of 30 or more students may, on the average, exceed the 80th percentile when given an equal amount of tutorial assistance. This dramatic gain in achievement is, of course, one of those "all other things being equal" conclusions that is easily disturbed by a variety of confounding variables.

Figure 1: Meta-Analysis of Class Size and Student Achievement



Indeed, when Glass and Smith limited their analysis to the effects of naturally occurring class size variations, achievement gains were found to be less than 10 percentile points when classes of 40 or more students per teacher were compared with one-on-one tutorials. In the body of their 1978 report, Glass and Smith examined a variety of factors that might affect student achievement gains. They divided the research studies into sub-groups based on age, grade, length of time students were exposed to instruction within a specific class, etc. Regardless of how the studies were grouped, or which ones were removed to eliminate potentially spurious reasons for the achievement effects, they found significant curvilinear regression lines in all study groups. All of the regression lines lay somewhere between the large gains found in the "Well Controlled" studies (14 studies -- 110 comparisons) and the small gains found in the "Poorly Controlled" research studies (62 studies -- 615 comparisons). They concluded that small classes produce much higher achievement than large classes; but that large classes are only slightly better than very large classes. They found that it did not matter whether the class size and achievement relationship was studied for older versus younger children, or whether tests measured reading, math or science achievement. The academic superiority of small classes was basically the same. In addition to the importance of controlling for student assignment, Glass and Smith found that studies in which pupils are taught in small classes for over 100 hours are much more

likely to show superiority than studies in which instruction lasted for fewer than 100 hours. Glass and Smith concluded their 1978 work by stating:

> Research on class-size and achievement is a particularly complex body of findings to integrate and understand. The integration of this literature has required more sophisticated analysis than has previously been applied to the problem. The meta-analysis of the research reported here has drawn heavily on precise quantitative description and analysis. A clear and strong relationship between class-size and achievement has emerged. The relationship seems slightly stronger at the secondary grades than the elementary grades; but it does not differ appreciably across different school subjects, levels of pupil IQ, or several other obvious demographic features of classrooms.

Moreover, they insisted,

> The relationship is seen most clearly in well-controlled studies in which pupils were randomly assigned to classes of different sizes. Taking all findings of this meta-analysis into account, it is safe to say that between class-sizes of 40 pupils and one pupil lie more than 30 percentile ranks of achievement. The difference in achievement resulting from instruction in groups of 20 pupils and groups of 10 can be larger than 10 percentile ranks in the central regions of the distribution. There is little doubt that, other things equal, more is learned in smaller classes.

A Firestorm of Criticism and Controversy. The Glass and Smith study was sharply criticized by Robinson and Wittebols, representing the Educational Research Service (ERS), who published their objections in the December, 1980, *Phi Delta Kappan*. Their major objection was that the "well-controlled" curve was based on too few studies, and that some of these dealt with college classrooms and individual tutoring arrangements. Why this objection was published by the *Phi Delta Kappan* editors is most

baffling. Glass and Smith had specifically anticipated such a criticism and had recalculated the achievement curve without the college age students and without the tutorial studies, demonstrating that removing these studies did not materially alter the findings (Glass and Smith, 1978, p. 43).

Additionally, the ERS study launched an attack on the meta-analysis technique itself. They argued that meta-analysis obliterates important distinctions between studies, and warned of the dangers of making policy decisions based on the half of the curve relating achievement to class sizes with fewer than 20 students. The ERS criticism of meta-analysis was followed by what can only be characterized as a singularly inept review of the literature relating class size to student achievement.

While cautioning against overreliance on inadequate research, the ERS reviewers proceeded to collect about 80 "achievement" studies (many of them excluded by Glass and Smith because they contained no usable data) and sorted them into three grade-level groups: K-3, 4-8, and 9-12 (the ERS additionally collected another 20 studies, which they used to augment the 80 and obtain clusters of studies dealing with subject areas, instructional methods, and non-achievement outcomes). Within each group, they categorized the results as favoring small classes, large classes or showing no difference and then tallied the results and came up with percentages of studies favoring small classes. Ignoring the magnitude of the differences and the nature of student assignment procedures, the ERS reviewers concluded that smaller classes may be beneficial in the early primary grades,

but make little difference for students in the middle and the secondary grades.

The techniques used in their analysis are troublesome in two important respects. First, studies showing measurable, statistically insignificant, achievement effects were classified as favoring neither large nor small classes. Such a classification is simply wrong! Since class size effects are relatively small and often overshadowed by other factors, review techniques need to give full weight to the measured differences found in every study. Modest, but statistically unreliable differences need to be converted to a common metric and statistically combined before a legitimate conclusion regarding overall results can be drawn. Repeatedly discounting small differences leads to the erroneous conclusion that these differences are not real. The meta-analytic technique overcomes this error and leads to a more reliable result.

As argued by Robinson and Wittehols, meta-analysis does obscure differences among studies, but that is just what it is intended to do. Meta-analysis was developed expressly to determine whether small differences, repeatedly confirmed in multiple studies, warrant a conclusion that these small effects are real and reliable. The ERS approach neglects, rather than analyzes, the cumulative evidence of a link between class size and achievement and overlooks entirely the need to combine numerous studies in order to identify persistent but small effects. Although Glass and Smith

ignore differences among studies, the ERS approach obliterates commonalities.

Glass and Smith reanalyzed the class size research data in 1982, this time joined by Cahen and Filby (Glass, et al., 1982). The reanalysis affirmed the original conclusion: there is a statistically significant correlation between student achievement and class size. Student achievement decreases as class sizes get larger. The effect can be found at all grade levels, in all subject areas, and for all types of students regardless of socio-economic status, ability or prior achievement levels.

Controversy concerning the use of meta-analysis continued for several years, but its stongly formed conclusions continued to dominate the scholarly literature. Aside from the ERS study which sought to dismiss the technique altogether, most academics attempted to refine and strengthen the procedure. Hedges and Stock (1983) contended that the meta-analytic technique was "suboptimal" primarily because it uses a statistically biased increase of achievement, overestimating effect-sizes in small samples. Using the Glass and Smith data, the class size curves were recalculated using Hedges' (1981) unbiased effect-size estimator. In the end, revision "made no difference" in the conclusion that class size significantly affects achievement (Hedges and Stock, 1983, p. 83).

A more substantive critique of the Glass and Smith meta-analysis was offered by Slavin (1984, 1989). He challenged the use of a number of the Glass and Smith studies, arguing that they are wholly inappropriate to the

substantive issue at hand. Overall, he argued, the use of meta-analysis should be moderated in order to produce what he calls a "best evidence" review of the literature, which essentially combines the quantification of effect sizes and the systematic literature search and inclusioon procedures of meta-analysis with the description of individual studies and methodological and substantive issues characteristic of traditional literature reviews. Best-evidence synthesis applies well-justified prior criteria to select those studies that consitute the main body of the review.

Slavin pointed out that in the Glass and Smith meta-analysis "the evidence above class size one is weak; three of the four effect sizes in the 2-5 student range are from a study by Moody, Bausell and Jenkins (1973) in which the interventions were applied for a total of 30 minutes. Slavin concluded that the Glass and Smith meta-analysis statistically homogenized the findings of research studies in such a way as to lose helpful information or guidelines for those making class size decisions affecting pupils with specific abilities, in specific grades, or in specific areas.

While no reputable scholars continue to challenge the basic finding that achievement increases as class size goes down, there are important disagreements over how large the gains may be and how they are produced. State legislators are no longer awaiting better evidence. They have accepted current evidence as convincing and are mandating reduction in student/teacher ratios. Eight states have acted to reduce class size: Arkansas, Indiana, Florida, Nevada, South Carolina, Tennessee, Texas, and

West Virginia. Five other states - California, Minnesota, New Jersey, Virginia, and Wisconsin are presently considering class size reduction legislation. It is largely because of state involvement in this area that primary research into class size effects has continued.

Preliminary results from two states, Indiana and Tennessee, support the conclusion that students in the reduced classes achieve higher standardized test scores than their peers in regular sized classes. Data from these states indicate that placing an aide in regular size classes improves learning outcomes, albeit less dramatically than in the reduced size classes. Students in small classes also score higher on measures of self-concept and motivation.

Indiana's class reduction policy, piloted in a controlled test program in 1981, now reduces K-3 classes throughout the state to an 18 to 1 ratio by adding more teachers, where facilities permit and by providing funding for aides where space limitations prevent smaller class size. Funding is also provided to give teachers in-service training.

Four studies have reported substantial achievement gains from this class reduction policy (Indiana State Department of Education, 1983; Gilman and Antes, 1985; Swan, 1985; and, Vanble and Antes, 1988). In an early study, two successive classes of first graders were compared. Test scores for 1984-85 were significantly higher than those from the previous year's larger classes (Gilman and Antes, 1985). Students in smaller classes did much better than those where aides were used to lower the pupil/adult ratio. A

second Indiana study (Swan, 1985) found gains for the small classes in 47 of 56 test score comparisons. Thirty-three of these comparisons were statistically significant. The other 14, while not reliable in themselves, would add positively to a meta-analysis such as the one developed by Glass and his colleagues. Of the nine comparisons showing lower achievement for the small classes, none were large enough to reach statistical significance.

Tennessee, like Indiana, has encouraged careful study of its class reduction policy. In 1985, a statewide study of class size reductions was piloted prior to possible legislation mandating maximum class size levels. Data on the Tennessee program, dubbed Project STAR (Student/Teacher Achievement Ratio), are reported in Bain, et al., (1986, a pilot-project report); and, Achilles, et al., (1987).

Beginning in the 1984-85 school year, students from participating school districts were placed in three groups: small classes of 13 to 17 students, regular classes of 22 to 25 students, and regular classes with an aide. First year data indicated that students in the small classes score higher on achievement tests than in either regular classes or classes with aides. This achievement advantage is larger for math than reading. Students in small classes also score higher on academic self-concept measures (Achilles, et al., 1987).

Toward a Theory of Class Size Effects

Perhaps the greatest weakness in the literature on class size is the lack of a convincing theory of how reduced student/teacher ratios are actually turned into achievement gains for children. The meta-analysis produced by Glass and his colleagues is widely perceived to document the existence of rather small gains for children exposed to ordinary classes, and highlighting much larger effects as overall class size approaches one-to-one tutoring. But why should such a relationship between class size and student achievement occur? This question is almost never asked. It certainly has not been satisfactorily answered to date.

Teacher convictions to the contrary not withstanding, most observers share the conclusion expressed by Glass and Smith in their 1978 study: modest changes in the size of ordinary classes can not produce substantial achievement gains. They found that achievement gains resulting from a reduction in class size from 40 to about 20 students per teacher amounted to only about 6 percentile points on a typical achievement test. That is, a student who would finish the year at the 50th percentile in a class of 40 students would be expected to score at the 56th percentile if the class had only 20 students in it. This translates to less than one-third of a percentile point per student, and is generally regarded in the literature as too small to be taken seriously. As Glass and Smith (1978, p. 38) put it, "The major benefits from reduced class-size are obtained as size is reduced below 20 pupils" (see also, Slavin, 1989).

This conclusion is very misleading, however. Data from Tennessee and Indiana suggest that 6 percentile ranks may be a very low estimate of the actual achievement gains to be produced through lowering class size to 20 or fewer students. Even if 6 percent is all that can be gained, however, achievement gains will be substantial if class reductions are maintained over a child's entire thirteen year career in the public schools. As shown in Figure 2, the cumulative effects of the modest achievement gains documented in the research literature can be startlingly large when sustained over several years.[1] Based on the conservative estimate provided by Glass et al., (1978) the cumulative effect of reducing class size from 29 (the average class size in California's Riverside and San Bernardino Counties) to 23 (the statewide student/teacher ratio) would produce a cumulative gain in achievement of more than 16 percentage points. That is, the average

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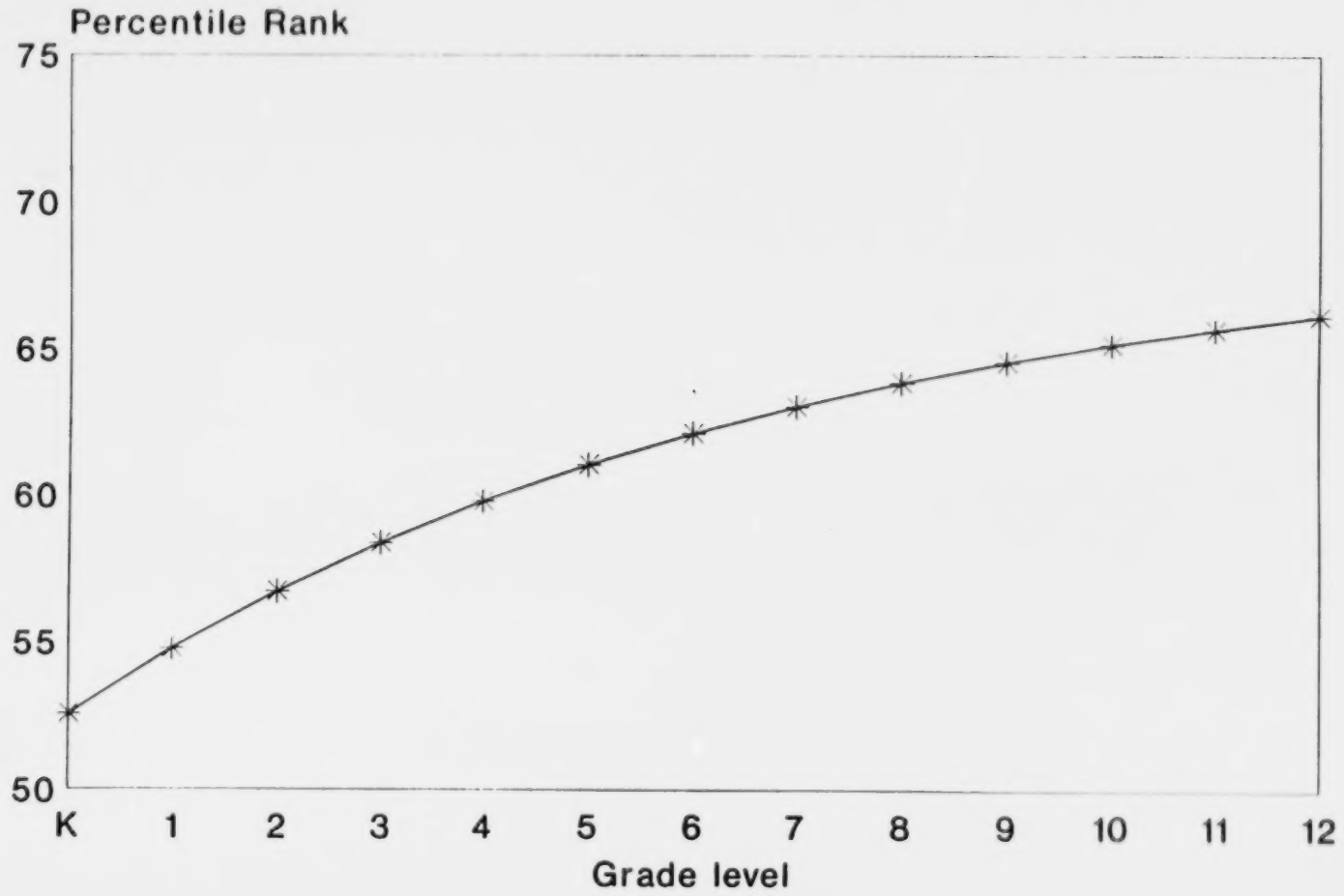
[1] The graph of achievement gain is a curve, because no child can exceed the 100th percentile rank on any standardized achievement test. Hence, children who have had the advantage of smaller classes in earlier years will have a higher starting point and will not be able to move as far. This curve might well be a straight line if criterion-referenced tests were used. There is no reason to believe that high achieving children benefit less from smaller classes, only that they can never do better than the highest percentile rank on a standardized measurement.

Figure 2
Impact of Class Size Over K-12 Career



(Class Size Reduction from 29 to 23)

CERC @ UCR, 7/89

kindergartners in these two counties -- those expected to graduate from high school at exactly the 50th percentile -- would be expected to exceed the 66th percentile if all their classes were reduced to 23 students.

Prediction without Understanding

Statistical analyses like the one just presented are of limited value, however, because they encourage prediction without understanding. Why do the smaller classes do better? And above all, why does the relationship between achievement and class size follow a curve rather than a straight line? What we need is a theory of class size effects -- a convincing analysis of classroom operations that explains rather than simply models the statistical relationships found in the data. Theoretical explanation of class size effects would provide school managers and policy makers with the means of planning for increased productivity by assisting them in development of specific strategies for coping with the deleterious effects of large classes. Current class size policy debates almost always pit fiscal conservatives against teacher advocates because they lack any rational way of explaining why smaller classes work better and, thus, provide no basis for determining whether one approach to reducing class size is better than another.

Developing a Theoretical Explanation

A recent cartoon in the Los Angeles Times suggests one possible explanation for declining achievement in large classes. The cartoon shows a teacher standing before her principal's desk and saying, "Mr. Jones, we simply must do something about the number of children in my class. The bell keeps ringing before I finish calling the role." This teacher is raising the possibility that the primary reason for greater productivity in small classes is expansion of "down time" in larger classes due to the time it takes to call role, collect and pass out papers, check on student understanding, discipline misbehaving students, or other non-instructional activities that grow in direct proportion to the number of students in the class. We might call this the "Classroom Overhead" theory, since it assumes that the primary source of declining achievement is the gradual expansion of non-instructional overhead teachers must expend in order to keep their classrooms operating smoothly.

As logical as it may seem, however, this Classroom Overhead theory is only one possible explanation for reduced performance in large classes. At least three other theories might logically account for some or all of the achievement gains in smaller classes. Student interaction time, for example, might account for a significant portion of the reduced productivity in larger classes. While the teacher's overhead workload would increase incrementally with each new student, student interaction time would rise exponentially. Imagine students trying to reach consensus on a discussion topic, or settling

down after a recess break. Adding one new student to the group adds not just a single opportunity for expanding the time needed to bring closure to the activity, but each new student has an opportunity to interact with all of the students already present in the class. The effects of this exponential growth in learning time can be readily seen in small groups. When a second student joins a one-on-one tutorial, the teacher need only to interact with one other student. The addition of a third student creates two opportunities for each student interaction (a total of three pairs); the fourth student creates a third interaction for each student (making a total of six pairs). By the time the 31st student is being added to a class of 30, the number of student interaction opportunities is jumping from 435 to 465. This "Student Interaction Time" theory predicts an exponential loss in effectiveness as classes grow in size. Losses may not gain indefinitely with class size. If, for example, students no longer relate to the whole class, the interaction loss will be reduced. In typical public school classes, however, both teachers and students view the whole class as a single group.

A third possibility was identified in 1987 by an English researcher (Preece, 1987). Preece noted the lack of theoretical foundation for the meta-analysis developed by Glass and proposed that the source of declining performance in large classes arises because teachers tend to adjust their instructional strategies to the least able students in a class. He noted that when students are randomly assigned to classes from a normally distributed population, larger classes will have a statistically greater chance of getting

the lowest ability students. This is not the result of any planning on the part of educators -- it occurs simply because low ability students are not evenly distributed. Ability near the average for all students is much more frequent than either very high or very low ability. Hence, the full range of student ability will most likely be found in very large classes. Smaller classes are less likely to be as divergent. Like the Student Interaction Time theory, this "Teacher Adjustment to Student Ability" theory predicts a curvilinear relationship between achievement and class size. The predicted curve has a very different shape than the previous one, however, allowing us to determine which theory best fits the available data.

A fourth theory aimed at accounting for the effects of class size might be called the "Fixed Instructional Resource" theory. Since the evidence is indisputable that a tutorial is the most effective teaching arrangement, we could hypothesize that the capacity of a teacher is limited and has to be spread divided among all of the students in any given class. That is, we could assume that adding a second student to a class divides the teacher's contribution to the learning of each child in half, the third student causes the resource to be divided into thirds, etc. Thus when the 31st student is added to a class of 30 the students who used to get 1/30th of the teacher's instructional attention now get only 1/31st of that fixed resource. The theory of Fixed Instructional Resources, like the two previous examples, would lead us to expect a curvilinear relationship between class size and achievement. The curve predicted by this theory comes very close to the

one developed by Preece (1987), so it may not be possible to determine which of the two is right on the basis of achievement data alone.

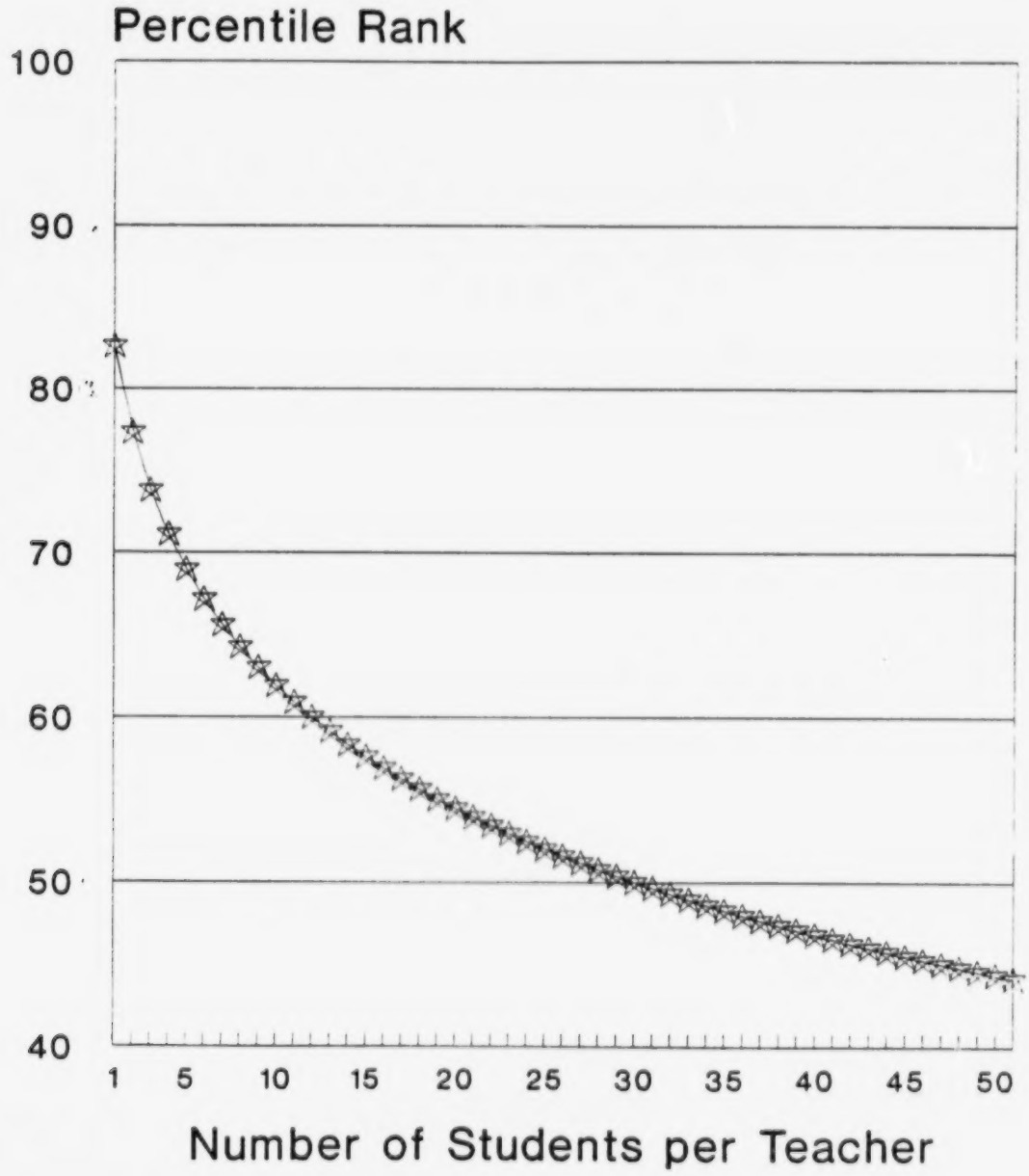
It is possible, however, to subject each of these four theories to a test by clearly specifying what each predicts regarding the relationship between achievement and class size and then testing whether their predictions match available research data. Glass and Smith performed a substantial public service in this connection by publishing the data used in their 1978 study. The following paragraphs summarize what happens when this data set is re-analyzed from the perspective of each of these four theories.

A report on the results of testing each of these models against the Glass and Smith data is presented in Appendix A. To summarize this testing process: the Fixed Instructional Resource theory does the best job of describing the empirical data. This model is slightly better than the one developed by Preece. Not only are these theories more robust in predicting the results of research to date, the Fixed Instructional Resource model completely absorbs the explanatory power of the Classroom Overhead and Student Interaction Time models.

The logarithmic curve that results from applying the Fixed Instructional Resources theory to the Glass and Smith data is reproduced here as Figure 3. This matches the effects curve generated by Preece almost exactly, and is the most reliable measure available to date regarding the link between class size and student achievement.

Figure 3

The Impact of Class Size on Achievement



Re-analysis of Smith & Glass (1978)

Summary

Three conclusions supported by this theoretical comparison process are vitally important to school managers and policy makers. First, there are sound reasons for the increased achievement found in smaller classes -- teachers must divide their attention among the students they face, and they must adjust instructional strategies to fit the needs of all students in the class. Second, even though there are a broad range of confounding factors, and great variations in the effectiveness of individual teachers, it is possible to estimate with some confidence the effects of class size reduction on student achievement. Third, since it is possible to understand how teachers of smaller classes secure improved results, it is possible to begin investigating whether these results can be achieved in any other way. If teachers are adjusting to low achieving students, can the effects of class size be moderated by training teachers to compensate for this natural tendency? And if teachers are limited by their ability to give time and attention to all students in the class, is it possible to develop strategies that make their work more effective and more efficient?

Exactly How do Changes in the Student/Teacher Ratio Produce Learning Outcomes?

While statistical analysis of test score data sheds some light on competing theories of how reducing class size improves student learning, a better approach is to closely examine changes in the attitudes and behavior of teachers and students. A few good research studies have tried to do just that. This line of research is not as well developed as that dealing with achievement and it examines some of the most subtle and complex aspects of the teaching and learning process. Nevertheless, a view of this research provides important insights into exactly how class size changes are turned into student learning effects. The review of this literature presented below is divided into three such sections. The first looks at quantitative studies of classroom processes, the second at experimental interactions, and the third summarizes data in changes in teacher perceptions from the Tennessee class size project.

Quantitative Studies of Classroom Process Factors. A number of researchers have attempted to measure educational processes and participant outcomes which they felt might bridge the gap between an alteration in class size and a measurable achievement effect. Students have been tested to measure their attitudes towards school and their self-concept (Pugh, 1965; Bolander, 1973; and, Buczeck, 1981). Attendance patterns have been examined (Lundberg, 1947 and Counelis, 1970). Teachers have answered questionnaires, granted interviews, and responded to surveys concerning the

size of their classes and their levels of stress, their own perceptions of their effectiveness in classes of varying sizes, and indications of their overall morale and satisfaction with teaching as a profession (Bjarnason, 1925; Anderson, 1950; Brown, 1984; and, Steiner, 1986). Parents and administrators have also responded to surveys and questionnaires regarding their perceptions of their students' performances and well-being (Probst-Kowal, 1986; Indiana Department of Education, 1983; and, Olsen, 1971).

Findings from 59 studies of this nature have been summarized via meta-analysis to determine what trends could be ascertained from the combined data (Smith and Glass, 1980). In this meta-analysis, effect sizes were divided into three subgroups: (1) student motivation, self-concept, attendance, etc.; (2) teacher morale, attitude towards students, perceptions and satisfaction; and, (3) instructional effects, such as the frequency of teacher-student interactions, teacher's knowledge of students, student attention, and on-task behavior. As in the achievement meta-analysis, a logarithmic model provides the best fit for this data. The authors report that,

> the logarithmic model arose from the expectation that class size and non-achievement effects might be related in something of a nonlinear fashion, reasoning that one pupil with one teacher acquires an interest in the subject of intensity *A*, two pupils develop somewhat less intense interest, three even less, and so on. Furthermore, the drop in interest from one to two pupils could be expected to be larger than the drop from two to three, which in turn is probably larger than the drop from three to four, and so on. (Smith and Glass, 1980, p. 424)

The resulting curves for the three affective domains indicate that,

> reducing class size has beneficial effects both on cognitive and affective outcomes and on the teaching process itself. (Smith and Glass, 1980, p. 112)

Looking Inside Classrooms. Several recent class size research studies have followed Lindburg's suggestion (1970, p. 16) and gone inside the classroom to identify process changes related to student performance. In general, this line of research centers on critical aspects of teachers' instructional behavior and examines whether these behaviors are necessarily limited to small classes.

In Canada, for instance, the Toronto Board of Education sponsored an experimental study of the cognitive, affective and management differences between small and large classes (Wright, 1977). Using sixty-two upper elementary classes in eleven schools, four different class sizes were created to investigate the effects on:

a) teacher's expectations;

b) the attitudes and opinions of students, parents, and teachers;

c) student achievement in reading vocabulary, mathematics, composition, and art;

d) the academic self-concept of students; and,

e) classroom process variables -- teacher-pupil interaction, pupil participation, method of instruction, subject emphasis, use of educational resources, classroom atmosphere.

Prior to the study, teachers had expected that the smaller classes (16,

23) would: (1) enable them to provide for more individualization, (2) develop better rapport with pupils, (3) result in academic improvement, (4) enhance pupil self-confidence and independence, and (5) create a more relaxed and enjoyable classroom environment. Substantial differences were found in each of these areas. Teachers reported that they made substantive changes in classroom layout, student evaluation, and classroom management and supervision. Standardized tests used to measure students' academic achievement and self-concept showed the smaller classes to be beneficial, overall, but these results were only statistically significant in the area of mathematics concepts.

Classroom observers found class size did not materially affect the way teachers divided their time among lecture, seatwork and student interaction. Wright concluded, therefore,

> that pupils in classes of 16 and 23 had more individual interactions with their teachers simply because the amount of time spent talking to pupils individually was being distributed among fewer pupils. (Wright, 1977, p. 119)

This division of a fixed teaching resource over the varying number of students in a classroom is just what the logarithmic curve produced through meta-analysis.

Experimental Change. Another qualitative study sought to identify changes in instructional processes and in teacher and student behavior when class size is reduced (Filby, et al., 1980). Class size was experimentally reduced midway through the year in four second grade classrooms by

removing one-third of the children in each class to a newly created class. The four classes were studied throughout the year, in both the "large" class and the "small" class phase, so that comparisons could be made.

Many different methods were used -- naturalistic observations, quantitative observations, teachers' journals, and interviews. Participating teachers were encouraged to take advantage of the smaller classes in whatever way they considered appropriate. The authors concluded that classroom management was easier and more effective when class size was reduced. In the large classes, teachers commented that they spent more time disciplining and less time teaching. Student attention rates were generally higher in the smaller classes. In one site, students were on-task an average of 56% of the time during reading and math periods in the large class phase. In the small classes, this figure rose to 72%. This increase was accompanied by a decrease in time spent waiting for help or misbehaving. Students were reported to be absent less often in the small classes. More individualization took place in the smaller classes and teachers felt they knew more about how each student was performing. Curriculum enrichment also occurred, although these varied more from class to class. Students completed lessons more quickly, so they progressed through the curriculum at an accelerated rate.

Most changes represented modifications or improvements within the teacher's existing style and plan of instruction. Teachers did not change their basic approach to classroom management or to the curriculum. They were, however, able to do more or better what they had already intended.

Johnston and Lintz (1989, p. 2) summarize the contribution of the Filby, et al. study as, "going beyond the black box'" approach to student outcomes, while being substantially "limited by the number of classrooms pupils, and teacher involved".

Teacher Perceptions of Change. Researchers working on the effects of Tennessee's Project STAR interviewed 337 first grade teachers, who had worked in the 1986-87 school year in either a small class, a large class or a large class with a classroom aide (Johnston and Lintz, 1989). These interviews generally corroborate the findings from the experimental study reported in Filby, et al. (1980). The teachers in small classes report substantially different classroom experiences in eight areas. They reported:

1. Being aware of more space in the classroom, resulting in more work space for children, easier movement within the classroom, and less misbehavior. They also reported a lower level of noise in the classroom.

2. Using learning centers more frequently than they had in the past and feeling that their utilization of the centers was more beneficial.

3. A close, family-like atmosphere characterized by a high degree of cooperation among children.

4. An increase in the number and complexity of enrichment activities -- field trips, cooking and art projects.

5. A smaller number of student discipline problems.

6. An ability to evaluate student work more effectively by monitoring in-class performance and grading papers immediately.

Organizational and Fiscal Implications

While the benefits of class size reduction are substantial, the cost of securing them may be totally prohibitive. In a recent report, the U. S. Department of Education estimates that it would take $5 Billion to reduce class size in the nation's schools by a single student (Tomlinson, 1988). Given the current budget picture in Washington, this is tantamount to admitting that no serious effort in this direction can be supported by federal dollars.

As noted earlier, states have been moving toward reduced class size. The movement has been cautious, focusing largely on the lower elementary grades. State willingness to go further may be coming to an end, however. In West Virginia, for example, where class size reduction legislation was passed in the early 1980s, policy makers are now re-thinking the question. Serious consideration is being given to allowing class size to rise in order to finance higher teacher salaries.

Before dismissing the idea of class size reduction, however, three issues need to be explored. First, an estimate of the actual costs involved needs to be developed. Without a clear picture of the costs involved, it is too easy to imagine that policy makers are responding to special interests, or are simply unwilling to provide needed educational resources.

Second, an overall review of the links between school finance and various organizational factors affecting class size reduction is needed. School organization and finance are so closely intertwined that fairly small changes in operating arrangements can generate substantial changes in effective class size at a more reasonable cost than required for direct expansion of existing organizational arrangements.

Third, an analysis of alternative approaches to gaining some, if not all, of the benefits of class size reduction should be undertaken. Since we have some understanding of how smaller classes facilitate improved instruction, it is possible to look for opportunities to bring these improved instructional practices into ordinary school settings.

The High Cost of a Frontal Attack on Class Size

Schools are expensive. The average yearly cost of a typical California school is just about $2 million, including teacher and support salaries, capital outlay, maintenance and other necessary costs (PACE, 1988, p. 119). This translates into an average of $93,000 per classroom to maintain, staff and operate the average California classroom. This typical classroom currently serves 28 students (the average California class size according to the latest California Basic Education Data System figures).

Since existing classrooms cost about $93,000 per year, one way of estimating the cost of class size reduction would be to calculate how many more classes are needed and multiply that number by $93,000. Many would

argue that this estimate is too high because the new classrooms would each have fewer students. The smaller classes require fewer textbooks, fewer desks, and fewer supplies.

A lower cost estimate for creating and staffing new classrooms is produced if we include only building construction, maintenance and teacher salary costs. One district (Agronow, 1989) estimated that these costs (at elementary level) include:

$40,864 for purchase of a portable classroom

$ 8,029 for utilities and maintenance

$41,085 for elementary teacher salary & benefits.

This sums to a total of about $90,000 per year in the initial year when the additional portable classroom is purchased and about $50,000 in succeeding years.

This estimate is too low, however. No allowance is made for either increased support staff for the expanded teaching work force, or the acquisition of school sites on which to place the new classrooms. More importantly, no allowance is made for the fact that building and teacher costs, like that for all other goods and services, will rise as demand goes up. Any effort to substantially reduce class size would exacerbate teacher recruitment problems and strain construction capacity.

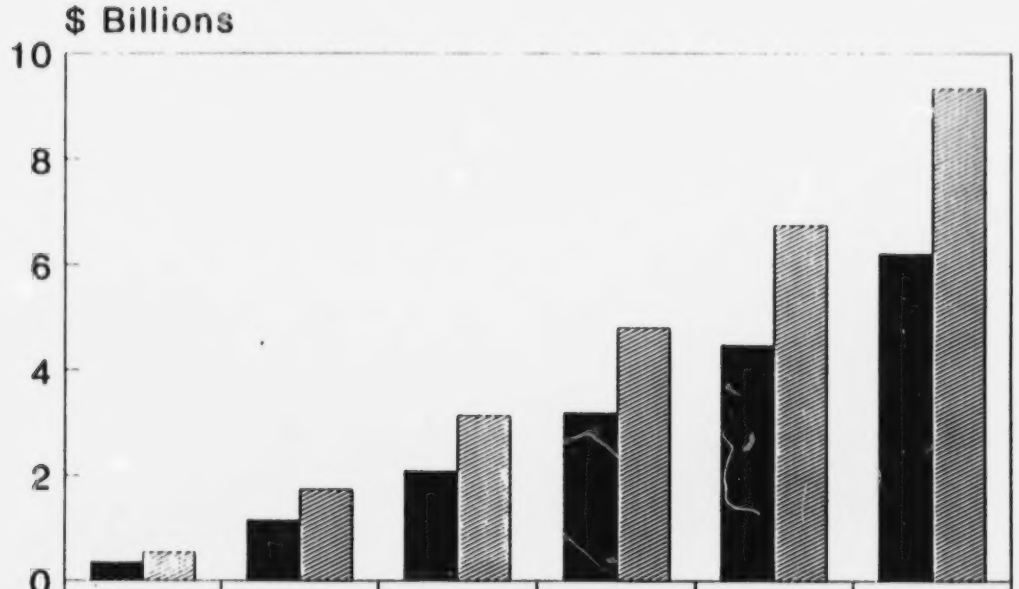
Figure 4 is a worksheet for estimating the amount of money needed to reduce California's class size from its current level of 28. Two estimates are given, one using a low estimate of $60,000 per classroom, the other using

the higher estimate of $90,000 per classroom. The cost estimates are depicted graphically in Figure 5. As the figures show, to remove just one student from each classroom in California would cost between $355,620,000 and $533,430,000, and this amount escalates sharply with each additional reduction. Given the fact that new educational resources to be derived from Proposition 98 will cover no more than a one student reduction in class size for California schools, there is no reason to believe that large class reductions will be made through construction of new classrooms and hiring new teachers to staff them.

Figure 4
California Class Size Reduction Costs
(Current Cost of Education = 14,409,071,122)
(Capital Outlay Costs = 427,223,007)

	Average Class Size						
	28	27	25	23	21	19	17
Regular ADA	$4,276,059						
Adult ADA	$204,651						
Number of Classrooms	$160,025	$165,952	$179,228	$194,813	$213,367	$235,827	$263,571
Cost per Classroom at $90,000	$90,000						
Additional Costs (x 1,000)		$533,430	$1,728,270	$3,130,920	$4,800,780	$6,738,750	$9,324,000
Cost per Classroom at $60,000	$60,000						
Additional Cost (x 1,000)		$355,620	$1,152,180	$2,087,280	$3,200,520	$4,492,500	$6,216,000

Figure 5
California Class Size Reduction Costs



	27	25	23	21	19	17
Low Estimate @ 60K	0.356	1.152	2.087	3.201	4.492	6.216
High Estimate @ 90K	0.533	1.728	3.131	4.801	6.739	9.324

Low Estimate @ 60K High Estimate @ 90K

Organizational Appoaches to the Problem

Since financing large numbers of new classrooms is prohibitively expensive, perhaps school policy makers should consider taking an organizational approach to lowering instructional group size. Class size in today's schools could be substantially reduced using existing resources if educators at all levels were committed to doing so. Doing so would require a willingness to reconsider long established patterns of organization and administration, however.

Scheduling and staffing are the two most important considerations in modifying existing instructional groups. Typically, school schedules are driven by equity and convenience considerations. Neither students nor staff can complain about being treated unfairly if all work in the same size groups and have the same hours each day. Moreover, even when classes and periods are treated as more or less interchangeable, scheduling difficulties are often encountered. Dissatisfaction among families or staff members is easily provoked when attempts are made to schedule instruction for varying size groups or stagger student attendance in order to make better use of school facilities. Despite the potential difficulties, however, aggressive scheduling changes could do much to lower instructional size for various groups of students for at least part of each school day.

Staffing patterns are often as constrained as class schedules in today's public schools. Teacher contracts specify maximum class sizes, staffing ratios for specialists, length of the school day, job assignment procedures, and a

variety of other matters that limit flexibility in staffing. California's current staffing patterns have a major impact on class size. Note, for example, that there are only 23 students for each classroom teacher in the state, but that the typical class contains 28 students (according to the latest CBEDS figures). This means that California schools presently employ just about 5 teachers for every 4 classes. And this does not count teacher aides, administrative staff, or other professionals such as librarians, psychologists and nurses. The motivation for this staffing pattern is not hard to understand. In order to free specialist teachers and other staff to provide more intensive services to special need children, the average class size in this state has been allowed to rise by five or more students per class. Without increasing total staff resources, redeploying these specialized staff members could serve to reduce instructional group size significantly.

Alternative Strategies for Reducing Instructional Group Size

Within reasonable resource constraints, at least three distinct strategies can be found for reducing class size: 1) redeploying critical staff members, 2) redistributing the students, and 3) incorporating small class instructional strategies into existing classrooms. Only a small amount of data are available regarding the relative costs of any of these alternatives. One early study (Levin, et al., 1984) tried to compare the cost of lengthening the school day, peer tutoring and computer assisted instruction with the direct class size reduction. While the data used in this study would not be

considered adequate by today's standards, they do suggest that the least expensive alternative was peer tutoring. Lengthening the school day was found to be the least cost-effective way of producing student achievement gains. Computer assisted instruction was found to be more beneficial, on a dollar for dollar basis, than adding new teachers and classrooms.

Redeploying Staff. Surprisingly large reductions in effective class size can be generated for various parts of the school day if existing staff resources are creatively managed. In one widely publicized plan, (Muellor, 1985) an elementary school day was divided so that a three-hour block of uninterrupted time was devoted exclusively to instruction in the core academic subjects -- language arts, reading, mathematics and social studies. During this period, all certificated staff take a class of about 15 students. Instruction during this three-hour period is protected from all interruptions -- no office announcements, no parties, no youngsters moving in and out of their classrooms, no assemblies. All of these activities are held during the remainder of the day when class size is allowed to rise to about 30 students. This frees specialist teachers to provide help to special need children, and gives teachers planning time.

Such a strategy could be applied to a typical California school of 696 students using the plan outlined in Figure 6. Based on the statewide average of 23 students per teacher, this typical elementary school is entitled to 30.4 FTE (Full Time Equivalent) teaching staff. Of this 30.4 FTE 24 are needed to meet with classes currently averaging 28 students. The remaining

24 students would be found in two special education classes for learning handicapped students. This leaves 4.4 FTE not assigned to regular teaching duties. As shown in Figure 6, typical assignments for the remaining full-time staff would include: two resource specialist teachers, a federally supported Chapter 1 teacher, and a school improvement program teacher. In addition, the school would have the services of instrumental and vocal music teachers for one day per week.

As indicated in the right hand column of Figure 6, even without considering the use of staggered lunch and recess schedules to reduce effective class size, the staff could be redeployed to produce an average class size of 18 students for about half of each child's school day. This class size can be reached if, during a four hour block of time, two-thirds of the regular students (about 450) are distributed among 25 of the teachers. The remaining third of the students would be in relatively large physical education and music classes or assigned as student aides and peer tutors to the learning handicapped students. The four hour block would be divided into three instructional periods so that each third of the students would spend part of this time in the special class groupings.

As shown at the bottom of the right hand column in Figure 6, if class sizes are expanded to 35 students during the remainder of the day, each teacher can be provided with a 30 minute preparation period, the special day classes returned to the current pattern, and specialist teachers freed to provide services to special need students.

Figure 6
Staffing Options
696 Student Elementary School

Current Staffing

24 Regular Teachers @ 28 Students = 672

2 Special Day Teachers @ 12 ea = 24

2 Resourse Teachers Pullout Programs = 0

1 School Improvement Teacher (Push-in) = 0

1 Chapter 1 Teacher Pull-out Program = 0

.4 Music Teachers on Teacher Breaks = 0

3 Teacher Aides

Total = 696

Core Instructional Program Staffing -- 4 Hours Per Day

25 Regular Teachers @ 18 Students = 450

3 Teachers (asst by 3 Aides) @ 54 ea = 162

2 Special Day Class @ 25 LH+Tut = 50

1 Music Class @ 34 Students = 34*

Total = 696

Alternate Staffi Arrangement -2 Hours Per Day

20 Teachers @ 35 = 665
2 SDC @ 12 = 24
1 Pull-out = 7
6 Prep @ 30 min = 0
2 Push-in = 0

Total = 696

* This will require expansion in musical staff from .4 to .67.

As noted above, no allowance is made in Figure 6 for the additional advantages that would accrue if staggered lunch and recess periods were used to further reduce effective class size during part of the school day. By rotating children through supervised lunch or recess periods for an hour or so each day, an additional class reduction of one or two students could be produced.

Administrators have a tendency to feel that the greatest stumbling block to reorganizing instructional programs along the lines suggested here springs from teacher contracts and work rules locking the present pattern into the system. While this may be true in some instances, the tradition of specialized staff created via various categorically funded programs is often a more serious problem. Teachers with specialized work assignments are frequently encumbered by three assumptions regarding their work. First, they are typically seen as having been funded to provide a particular set of narrowly defined instructional services. This assumption is often written into program laws and regulations, so it is not hard to understand. Nevertheless, it leads to a management approach that emphasizes keeping specialist activities separate from regular instruction and thus tends to create a work schedule for the specialists that disrupts rather than supports regular class activities.

The second assumption limiting coordination between specialist and regular teacher work activities is the view that the specialists are specially valuable and scarce resources. This leads to the assumption that scheduling

should be done at the convenience of the specialists. The result is an unfortunate contention between specialists and regular teachers for access to students. Specialists take special needs students out of regular classes when they "have a time slot open" rather than when it would contribute to an overall pattern of reduced class size.

Third, specialist teachers frequently view themselves as concerned with matters other than the core instructional program of the school. Often this involves critical student needs in areas such as physical, emotional or mental disabilities. Sometimes, when the specialists deal with student assessment and placement, the disconnection is expressed in the form of the specialists' identification with school administration and management rather than concentrating on instructional processes at all.

As important as the specialized services to special needs students are, it is quite appropriate to ask that they be justified against the 20% reduction in class size that could be produced if all teachers were assigned to regular teaching stations.

Redistributing the Students. While total reorganization of school staff use can lead to dramatic reductions in class size for critical parts of each school day, less sweeping changes could be made by individual teachers to reduce instructional group size in the school. The literature reviewed earlier in this report documents the importance of appropriate student grouping for instruction. Where teachers fail to group students into small groups, most of the advantages of class size reduction disappear. Hence, some class size

reduction benefits might be available to teachers who better utilize student grouping strategies in current classrooms.

Typically, teachers divide their classes into three groups and rotate among the clusters to provide direct instruction and individual guidance. While most teachers are introduced to a variety of strategies for conducting small-group instruction, few of these strategies are used in typical classrooms. Filby (1980) argues that teachers need better models for integrating small-group instruction into traditional classroom practices. Three factors control the effectiveness of instructional grouping: the method of student assignment, the tasks set for group members, and the access of students to needed resources (Klein, 1985). Ways of enhancing each of these elements can be provided to classroom teachers through staff development or clinical supervision processes.

Peer tutoring is another strategy for reorganizing students to reap some of the benefits of reduced class size. Peer tutors have the effect of multiplying teaching resources as well as reducing the number of students remaining for direct teaching. There are costs, as well as benefits, associated with peer tutoring, however. Teachers must organize the tutoring process and monitor its implementation (see, Bossert and Barnett, 1981).

Team teaching, while not ordinarily thought of as a class size reduction strategy, can be used to provide some opportunities for small group instruction. When two or more teachers share responsibility for the same

students, they are able to combine large and small group strategies in ways that are not possible for individual teachers.

Incorporating Small Class Instructional Strategies. A third general strategy for bringing the advantages of small class size into today's schools is to focus on the especially effective teaching practices found most often in small classes (ie., greater utilization of space, more individualized instruction, and enhanced teacher "with-it-ness", Filby, et. al., 1980). In addition to using small instructional groups more frequently, effective small classes have lower noise levels and fewer discipline problems. They also provide individual students with more one-on-one instructional time and permit teachers to respond more fully to diverse student interests and abilities.

While many of the desirable attributes of small classes are made possible through the lower workload and more spacious environment available to teachers fortunate enough to have them, it is also possible to incorporate these features into larger class settings. Use of these strategies would certainly not come without cost. At a minimum, substantial staff development programs are needed to both familiarize teachers with the effective small class techniques. Additionally, significant management time and effort will have to be devoted to assisting teachers in their implementation. More importantly, little is known about the extent to which these techniques can be effectively utilized with larger classes. A systematic program of experimentation and research is needed to test the viability of specific strategies in various classroom contexts.

Conclusion: Class Size in Policy Perspective

This report has examined the expansive research literature addressing the influence of class size on students and classrooms in the public schools. Eight basic conclusions were reached through this analysis:

1. Reducing class size has a substantial and cumulative effect on student learning. Students who would have graduated from high school at the 50th percentile in academic achievement could be expected to reach as high as the 66th percentile if class size were reduced by six students over their thirteen year career in the schools.

2. Class size research, and especially the effort to review and summarize key findings, has an especially unfortunate history. Researchers have designed their studies with different purposes in mind, and have not always used methods appropriate to the purposes of their study. Popular reviews are also biased in their selection of studies for analysis and their methods of interpretation.

3. Some of the most seriously misleading conclusions drawn by reviewers have been, surprisingly, repeated again and again in subsequent analyses. The two most important examples of oft-repeated but misleading interpretations are:

   Acceptance of an early conclusion from a 1978 meta-analysis by Glass and Smith that class size variations in the range between 20 and 40 students per teacher have only insignificant impact on achievement.

   Repeated reference to a wrong-headed review by the Educational Research Service (1980) asserting that class size reductions are more important at the elementary grade level.

4. Development of a theoretical framework for explaining how class size affects learning has been slow. It is possible to demonstrate, however, that the curvilinear relationship between class size and achievement is caused by the fact that teachers represent a Fixed Instructional Resource and that their time and attention are divided across the total number of students in the classroom. As a result, achievement losses mount rapidly for smaller classes and become successively smaller for each new student added to the class.

5. A number of important studies have demonstrated that achievement effects are mediated by changes in the way teachers handle their classroom responsibilities. Smaller classes learn more because teachers with fewer students can use classroom space and student grouping strategies more effectively. They are also able to reduce noise levels, maintain discipline, and improve the quality of time and attention given to each student.

6. While class size has a significant and reliable impact on learning, the costs of class size reduction are enormous. It is impossible to imagine public support for the level of funding needed to substantially reduce class size through simple expansion of school facilities and staff. Alternative strategies for reducing effective instuctional group size are available, however.

7. The most promising strategy for reducing instructional group size is redeployment of existing school staff for part or all of the school day. California schools have five certificated teachers for every four classes currently in operation. This means that with creative scheduling and assignment, instructional group size for at least one-half of every student's school day could be reduced from the current level of 28 students per teacher to about 18 students per teacher.

8. In addition to redeploying existing staff, some of the benefits of class size reduction can be gained through creative redistribution of students and through the incorporation into routine classroom practice of instructional techniques typically utilized in smaller classes.

Appendix A

Testing Competing Theories of Class Size Effects

Testing Competing Theories of Class Size Effects

The following paragraphs describe how each of the four competing theories of how class size variations affect student achievement were put to the test using data presented in Glass and Smith's original meta-analysis (1978).

The Classroom Overhead Theory. Put mathematically, the classroom overhead theory predicts that:

[1] (A)chievement = (T)utorial Level - (K) * (C)lass Size

where (K) is a constant representing the fractional loss in learning that takes place because each new student takes time and effort away from the effectiveness of a typical tutorial relationship.

Since the research studies reviewed by Glass and Smith report achievement differences arrived at by subtracting scores for larger classes from those of smaller classes, we must do some mathematical manipulation to equation [1] before testing it on the Glass and Smith data. Let L represent the large class size and S the small class size. Let A(L) be the achievement for the large classes and A(S) be the achievement of the small classes. Then, by substituting class size and the achievement levels for the large and small classes into equation [1] we get:

$$A(S) = T - K * S, \text{ and}$$
$$A(L) = T - K * L$$

Subtracting these two equations yields,

$$A(S) - A(L) = [T - K*S] - [T - K*L]$$

Let us call the difference between the two achievement scores Delta. Then,

$$Delta = T - K*S - T + K*L$$

Which simplifies to,

$$Delta = K*(L - S)$$

Linear regression analysis allows us to test whether this equation fits with the Glass and Smith data. The resulting regression equation does significantly predict the data in the study (the Multiple Correlation coefficient is .20, with a reliability of much less than .001). As shown in Figure 2, however, the regression line does not come very close to the data points.

The Student Interaction Theory. In order to test the Student Interaction Theory, a more complicated formula is needed. The number of student interactions possible in any group is given by the formula N(N-1)/2, where N is the number of students in the group. Thus the Student Interaction Theory expects the effectiveness of tutorial classes to be eroded according to the formula,

[2] (A)ch. = (T)utor - K*{(C)lass * [(C)lass - 1] / 2}

where K now represents the extent to which student interactions are interferring with instruction. With a little mathematical manipulation, the expression simplifies to,

$$(A)ch. = (T)utor - K/2 * (C)lass^{Squared} + K/2 * (C)lass$$

Once again, we can calculate the achievement difference, Delta, by substituting the (L)arge and (S)mall class sizes into the equation and subtracting. This yields the equation,

$$Delta = K*(L^2 - S^2) - K*(L - S)$$

This equation can also be submitted to regression analysis using the Glass and Smith data. When we do so, however, the result does not support Student Interaction Time as a possible explanation for declining achievement. Quite to the contrary, the regression coefficient for the first term $(L^2 - S^2)$ has the wrong sign, indicating that students just may learn more from increased interaction rather than less.

The Adjustment to Low Ability Students Theory. As Preece (1987) demonstrated, this theory is written mathematically as,

[3] (A)ch. = (T)utor - K*(L)east Able Student

In this case, Delta, the difference between Small and Large class achievement levels is a complex function of the student ability range in each class. Preece solved the problem, however, and demonstrates that this theory offers just about as strong an explanation of the Glass and Smith data as does Fixed Instructional Resource theory described next.

The Fixed Instructional Resource Theory. This theory is mathematically expressed by the expression,

[4] (A)ch. = (T)utor - K * the Logarithm [(C)lass]

The logarithm of the class size is used because this curve has just the mathematical property assumed by the theory -- the slope of the curve is proportional to the reciprocal of the class size. That is, the logarithm curve drops at the rate of 1/2 between 1 and 2, at a rate of 1/10 between 10 and 11, at a rate of 1/29 between 29 and 30, etc.

The when the Large and Small class sizes are substituted in equation [4] to calculate, Delta, the difference in achievement between classes, the expression reduces to,

Delta = K * Log(L/S)

Tested through regression analysis, this curve fits the data of the Glass and Smith study the best. The Multiple Correlation coefficient is .64, indicating that more than a third of the achievement differences are accounted for by this curve. More impressively, when the logarithmic curve is included in the same analysis with the Classroom Overhead and Student Interaction Time tests, it completely absorbs all of their explanatory power.

In terms of explanatory power, the four competing theories produce the following results:

Theory Title	Regression Results (Multiple R-Squared)
1. Classroom Overhead	.07
2. Student Interaction Time	.32
3. Adjustment to Least Able Student	.38
4. Fixed Instructional Resource	.41

In each case the Multiple Correlation coefficients are significant at well above the .01 level.

While analysis based on each of these theories produces significant explanatory power, the models assuming that teachers divide their attention among however many students they face, or adjust their teaching strategies to the least able members of the class are clearly more powerful predictors of the data available for analysis.

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